An Inquiry Into PBNM System Performance Required For Massive Scale Telecommunication Applications

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Doctorate of Philosophy (Engineering)

Year of Submission: 2006

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Certificate of Authorship/Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidate

Statement of Contribution

Contributions to Knowledge

We have proposed and tested three hypotheses about policy system performance in massive-scale applications:

- The *dominance* hypothesis which claims "PBNM system performance in large domains is dominated by the latency contribution of the inferencing sub-system".
- The *complexity* hypothesis which claims "Policy *complexity* as measured by PDN depth is a more significant factor in degrading performance than the *number* of policies in the system, in large domains."
- The *bindspace* hypothesis which claims "A novel *bind-space* conjunctive matching algorithm known as JukeBox will produce superior performance when compared to the current state of the art *assertion-space* algorithm known as Rete, for large domains."

All three hypotheses were *refuted* and the implications of these findings worked out as new knowledge about policy system performance.

In the course of examining these hypotheses, the following contributions were also made:

- Policy server *IO*, both network and file, is a significant performance issue and serves to limit the possible achievable performance of the system. This finding is at variance with the literature which assumes the inferencing algorithm is the cause of poor system performance.
- The *fanout* (outdegree) of a node within the policy discrimination network is a significant performance issue to policy server performance and is more important than the total number of policies installed in the system, their apparent complexity and whether conjunctive matching is employed or not.
- In general, it does not appear possible that a pure bindspace conjunctive matching algorithm can outperform an assertion-space algorithm such as hashed-equality Rete. This finding is at variance with the literature.
- We have discovered, documented and implemented a pure bindspace, unconstrained inferencing algorithm for conjunctive match which we called JukeBox. This algorithm is based on Perlin's MatchBox algorithm but does not have the significant limitations of his algorithm.

- We have identified and corrected an important error in Perlin's original and published Match-Box algorithm. This error prevented the matchbox operations from being generally correct.
- We have discovered, documented and implemented a method for using a binary-tree abstract data type as an efficient sparse store of N-dimensional data.
- We have provided a benchmarking procedure for measuring the performance of policy systems in a visible and repeatable manner. This process allows for the characterisation of the policy server's performance in terms of average latency and its variance.
- We have proposed the simple heuristic of $\lambda = 0.6\mu$ as a useful dimensioning tool for policy system performance planning. This relation is based on a simple consideration of the Pollaczek-Khinchine result from Queueing theory.
- We have provided an open experimental policy system and tool-set that facilitates the research into policy system performance. This tool-set consists of
  (a) the *Jive*! language for policy specification,
  (b) an optimising *compiler* for Jive! policies,
  (c) the *JitterBug* policy enforcement system and
  (d) *Geneva* - a configurable policy event generator.

Related Publications

- *Policy Interoperability and Network Autonomics*, Workshop on Autonomic Communications 2004 (WAC2004), Berlin, 2004, Springer-Verlag LNCS3457
- *Autonomics in Telecommunications Service Activation*, IEEE Workshop on Autonomic Communication for Evolvable Next Generation Networks, 7th International Symposium on Autonomous Decentralized Systems, 2005
- *Scalable Policy Enforcement and PBNM Benchmarking*, Ninth IFIP/IEEE International Symposium on Integrated Network Management (IM 2005), 2005 - poster session
- *Using Policy Mechanisms to Implement Autonomic Behaviour in Telecommunication Service Activation Processes*, 2006 IEEE/IFIP Network Operations & Management Symposium - accepted as a poster.

Abstract

PBNM systems have been proposed as a feasible technology for managing massive scale applications including telecommunication service management. What is not known is how this class of system performs under carrier-scale traffic loads. This research investigates this open question and concludes, subject to the considerations herein, this technology can provide services to large scale applications.

An in depth examination of several inferencing algorithms is made using experimental methods. The inferencing operation has been implicated as the major source of performance problems in rule based systems and we examine this. Moreover, these algorithms are of central importance to current and future context-aware, pervasive, mobile services. A novel algorithm, JukeBox, is proposed that is a correct, general and pure bindspace conjunctive match algorithm. It is compared to the current state of the art algorithm - Rete. We find that Rete is the superior algorithm when implemented using the hashed-equality variant.

We also conclude that IO is an important cause of PBNM system performance limitations and is perhaps of more significance than the implicated inferencing operations. However, inferencing can be a bottleneck to performance and we document the factors associated with this.

We describe a generally useful policy system benchmarking procedure that provides a visible, repeatable and measurable process for establishing a policy server's service rate characteristics. The service rate statistics, namely μ and σ, establish the limitations to policy system throughput. Combined with the offered traffic load to the server, using the statistic λ, we can provide a complete characterisation of system performance using the Pollaczek-Khinchine function. This characterisation allows us to make simple design and dimensioning heuristics that can be used to rate the policy system as a whole.